Measuring Strain in Trusses

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Abstract

Strain is an important quantity in engineering and materials science that relates the deformation of a material to its original length as a percent. Different materials exhibit particular qualities under loading, for example the amount of strain due to a certain magnitude of force, or the amount of strain that can be borne before failure. This experiment aims to compare the relative strengths of three common truss configurations by measuring the strain in their members under loading.

Introduction

Strain is defined as the ratio of the change in a sample material relative to its original length. Being able to easily calculate and measure strain is very important, in order to build and upkeep structures that are sturdy enough for safe use, while not wasting excess material

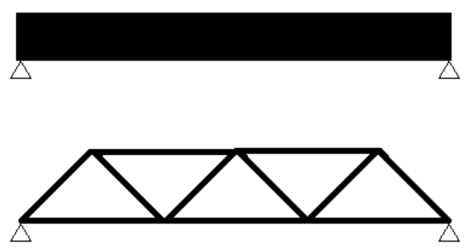
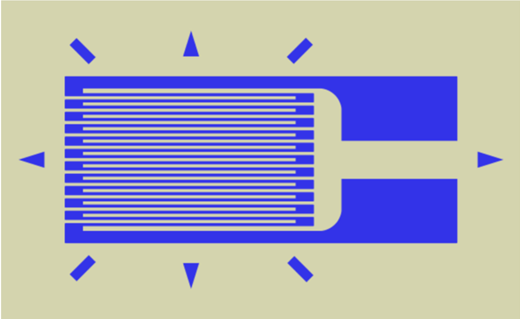


Figure 1. Beam (top) vs a simple truss

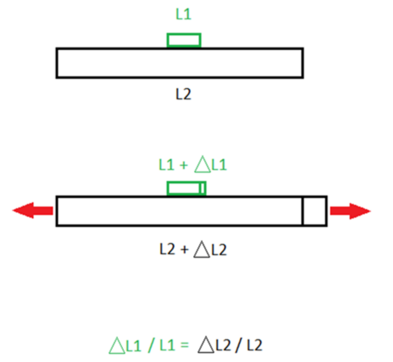
A beam is the most basic structure used in engineering. It is simply a straight piece of material that carries a load, as shown in Figure 1. A series of smaller beams can be combined into a truss shape. Trusses have the benefit of being stronger than a similarly dimensioned solid beam, but with much less material used and therefore less dead weight on the structure (Beer). Trusses also resist forces better than beams in skewed dimensions relative to their plane. For example, a beam might twist or bend unevenly, while a truss will direct the forces along its members and flex evenly throughout its structure. Many different truss designs exist and are commonly used in various applications, taking into account the dimensions, load, and aesthetics. The case I will be looking at is a truss that has to carry a load while spanning a horizontal gap, most commonly seen in a simple bridge.

The goal of this experiment is to measure strain to determine the overall strength and stability of a truss structure. A Warren truss should outperform a King's post truss and Queen's post truss in terms of minimizing strain under loading due to its uniform design and short member lengths.

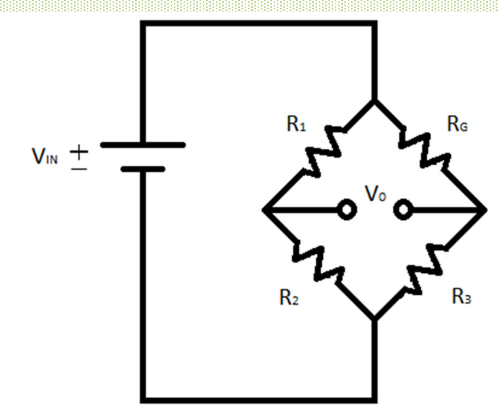
Theory



Enlarged diagram of a strain gauge. The large squares are solder pads for connecting to the circuit, and the lines are the resistance wire. Everything in blue is conducting, except for the radial alignment marks around the outside. (MADe)



Demonstration of how the strain in a member correlates to strain in the attached gauge.



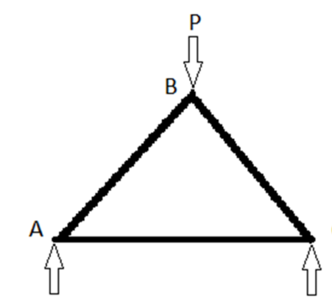
Wheatstone Bridge circuit, with strain gauge in "quarter bridge" configuration. Vin is the voltage supplied (in this case approx. 5V), R1 through R3 are the precision resistors, and RG is the strain gauge. VO is the output (measured) voltage.

$$R_G = \frac{R_1}{R_2} R_3$$

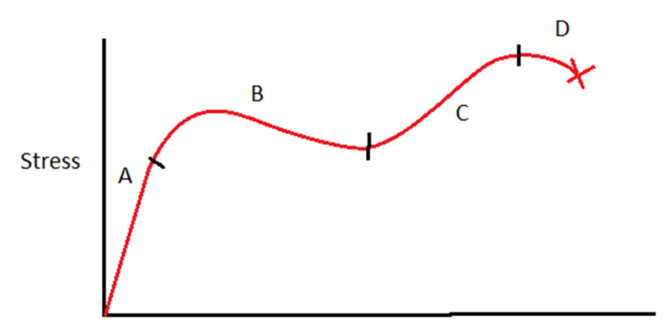
$$\epsilon = \frac{\Delta L}{L} = \frac{\Delta R / R}{K}$$

$$V_{out} = V_{in}\left(\frac{R_3}{R_3 + R_G} - \frac{R_2}{R_1 + R_2}\right)$$

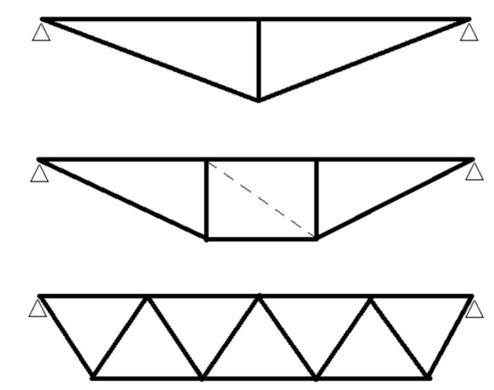
$$\epsilon = \frac{4V_{out}}{V_{in} K}$$



Method of Joints



Stress/ Strain curve. A: Elastic region. B: Yield strength. C: Strain-hardening. D: Necking. X: Rupture



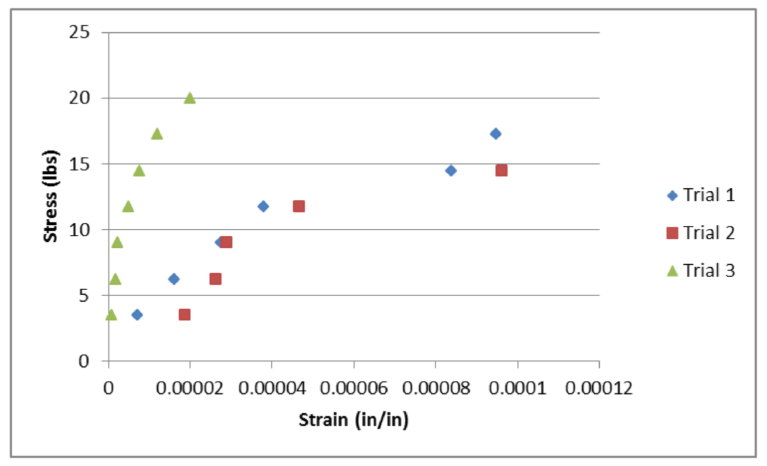
Basic structure designs. From top to bottom: King's Post, Queen's Post, Warren. The small triangles at the base on either end of each piece represent the supports.

Experiment

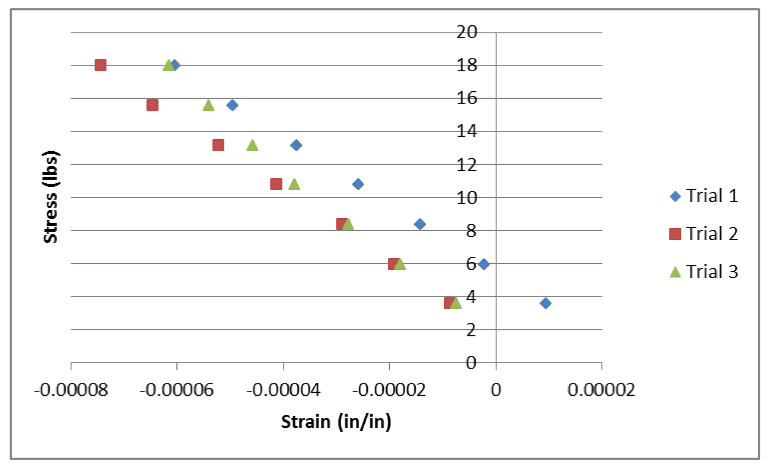
1. Attach the truss to the wire hangers, and attach circuit leads to one of its strain gauges.
2. Record the voltage output with no load, and then continue recording the voltage output as the load is increased in 2.2 lb. increments, up to 15.4 lbs.
3. Perform three trials of step two for each gauge, and for each gauge on each truss.

Data

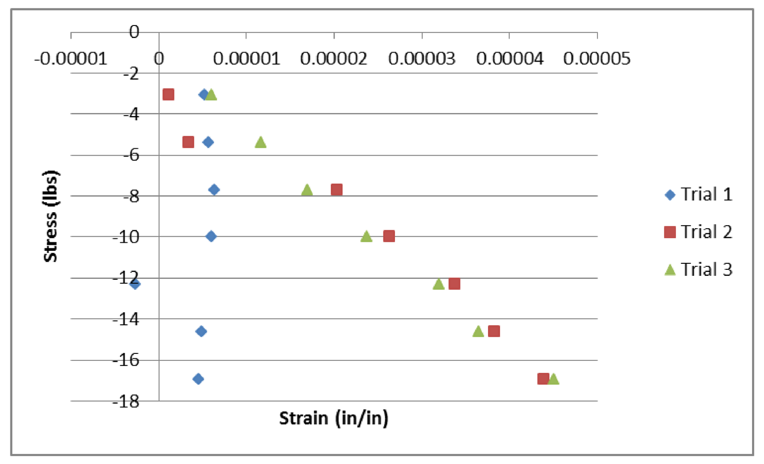
The measured strain was as expected: strain increased linearly with loading for all of the structures. Most prominently displayed is the maximum force member, as found by the method of joints. This is the particular member of a truss design that has the most stress directed to it. This allows us to compare the largest strain in each of the trusses.



Stress/ strain curve for gauge 1 on the King's post.

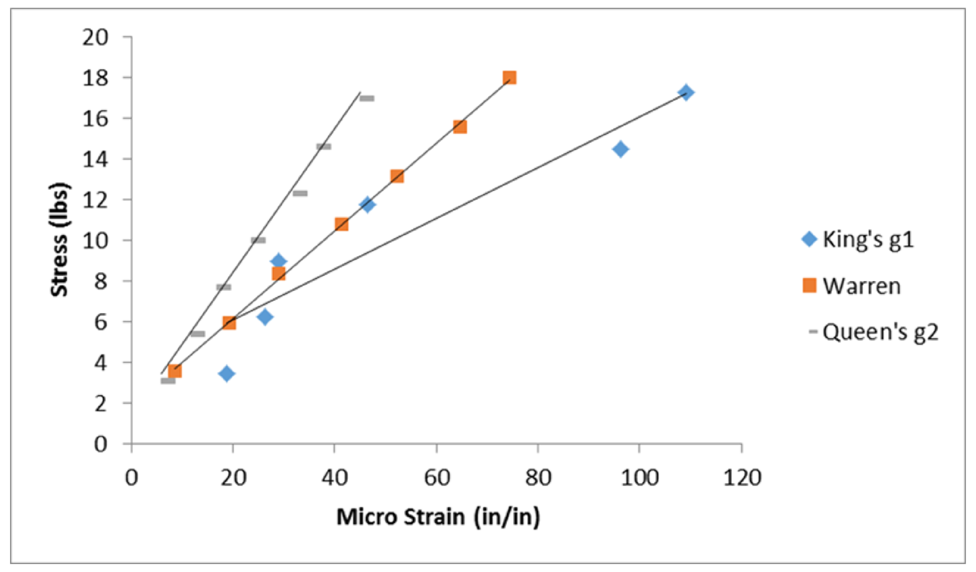


Stress/strain curve for gauge 1 on the Warren truss.



Stress/ Strain curve for gauge 2 on the Queen's post.

Absolute value of stress and strain for the major force member from each truss. The absolute value is used since some of the members were in tension and some were in compression.



Results and Conclusions

The King's Post had the greatest strain in its components. I attribute these findings to the nature of the designs, but they still each have their own strengths in different applications.

The King's post exhibited the highest overall strain reading in the entire experiment, **109** microstrain. One reason for this is it has the longest uninterrupted member of any of the designs, and this member is where the high reading occurred. Also, the King's post has the fewest number of components, so there are fewer pieces for the force to be distributed to.

The Warren truss was in the middle. While it was composed of equilateral triangles, so each member was the same length, one in reached **74** microstrain under load. This is fairly high for something that is a standard in engineering design, but while the one segment has a large strain, the rest of the truss was very, very low. A practical solution to this is that the high strain member can be made of stronger/ thicker material (at a higher price and weight addition to the structure), while the rest of the truss is made of much smaller members.

The Queen's post had the lowest strain in its major force member, at **45** microstrain. It ended up being the lowest overall sine it has a combination of the best attributes of the other two. It has the simplicity of the King's post that leads to a low dead weight on the structure, with the some of the extra support and shorter individual member lengths from the Warren truss.

References

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